THE UNIVERSITY OF ALBERTA

THE EFFECT OF CHRONIC EXERCISE ON THE WEIGHT OF SELECTED INTERNAL ORGANS OF YOUNG RATS

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF ARTS

FACULTY OF PHYSICAL EDUCATION

by

WENDY J. DAHLGREN

EDMONTON, Alberta

August, 1965

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APPROVAL SHEET

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Effect of Chronic Exercise on the Weight of Selected Organs in Young Rats" submitted by Wendy J. Dahlgren in partial fulfilment of the requirements for the degree Master of Arts.

ABSTRACT

It was the primary aim of this study to investigate the effect of chronic exercise over a five-week period on the weight of selected internal organs in young rats. Secondary purposes were to investigate: the effect of chronic exercise on the body weight of young rats, the relationship between the body weight and the weight of selected internal organs of young rats, and the relationship between the weights of various internal organs of young rats.

Sixty male Albino rats (Wistar strain) approximately five weeks of age were randomly assigned to one of three groups. The control animals were restricted to their small individual cages, as were those animals in the wet group except for once each exercise day when they were dipped in the swim water. The swim group was forced to swim five days weekly for periods up to 15 minutes with up to 5 per cent of their body weight attached to their tails. During the course of the experiment 15 rats were eliminated for various reasons, therefore 45 rats were used in the analysis of data. All rats were fed <u>ad libitum</u> from a stock diet. Body weight was recorded once each week. At the termination of the experimental period all rats were sacrificed, weighed, dissected, and the internal organs were removed in the following order: heart, liver, kidneys, adrenals, spleen, and testes. Organ weights were recorded as absolute weights and as relative weights, that is, as a ratio to final body weight.

Within the limits of the statistical techniques employed and the population investigated it was concluded that five weeks of chronic

exercise had no effect on the weight of the internal organs or on the body weight of the young rats. There was a significant and high correlation between the final body weight of young rats and the absolute weight of the heart and the liver. There were not high correlations between the final body weight and the weight (either absolute or relative) of the kidneys, spleen, adrenals, or testes, and none of the six internal organs tested showed a significant relationship to one another in terms of absolute or relative weight.

ACKNOWLEGEMENT

The author wishes to express her sincere appreciation and gratitude to her committee members, Dr. R. B. J. Macnab, Miss P. R. Conger, Dr. M. L. Howell, and Dr. P. Paez for their assistance throughout this thesis.

A special appreciation must go to Dr. Macnab and to Peter Carroll, a fellow graduate student, for the many hours they so willingly contributed and to Dr. D. C. Secord for his invaluable advise as a veterinary doctor.

Not to be forgotten are my family and friends for their patience, understanding, and assistance.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Numerous investigators (2, 4, 5, 13, 23, 35, 47, 67) have conducted studies to determine the physiological function of the internal organs during exercise, however relatively few studies have been conducted to determine the effect of long-continued (chronic) exercise on these variables. Although many of the alterations in the physiological function of internal organs are known, the permanency of these alterations is, to a large extent, a matter of surmise.

In 1628 Harvey (32:90) said "The more muscular and powerful men are, the firmer their flesh, the stronger, thicker, denser, and more fibrous their hearts, the thicker, closer, and stronger are the auricles and arteries". Some more recent invesigators have studied the effect of chronic exercise on internal organs, but the majority of this research has dealt specifically with the heart. In studies which have dealt with various organs, it is often difficult to assess the magnitude of the changes which occurred due to the fact that the data were not analysed statistically.

A further hindrance to this type of research has been the method in which the results were reported. In some studies organ weights were reported as absolute weights, while in others as relative weights, that is, in terms of organ weight per unit of body weight. It is obvious that these two procedures could produce different results, as a change in the body weight could, in itself, effect a change in the weight of the internal organ.

One problem in studying the effect of chronic exercise on internal organs using humans as subjects is the method of assessing any changes which may occur in the organs. Roentgenography has been used to assess the changes in some organs (for example the heart), however the reliability of this and similar methods of assessment is open to criticism. In animal research the organs can be removed and weighed, however the applicability of animal research to humans is always open to question. A further assumption in this approach is that organ weight reflects the physiological changes occurring.

Statement of the Problem

The purpose of this study was to investigate the effect of five weeks of chronic exercise on the weight of selected internal organs in young rats.

Subsidiary Problems

It was also the purpose of this study to investigate:

1. The effect of chronic exercise on the body weight of young rats.
2. The relationship between the weights of selected internal organs and the body weight of young rats.
3. The relationship between the weights of selected internal organs in young rats.

Hypotheses

The following null hypotheses were investigated:

1. There is no difference in the weight of selected internal organs in exercised and non-exercised young rats.
2. There is no difference in body weight of exercised and non-exercised young rats.

3. There is no relationship between the weights of selected internal organs and the body weights of young rats.
4. There is no relationship between the weights of selected internal organs of young rats.

Values of the Study

Scientific studies on the effects of chronic exercise on the internal organs are lacking, particularly with respect to the growing organism. If changes do occur in the organs following chronic exercise, the magnitude and direction of these changes should be clarified. Because changes are largely a matter of conjecture, both beneficial and adverse effects should be determined through a scientific investigation, thus adding to the body of knowlege of the effect of excerise and training on the total organism.

Limitations

1. The investigation was restricted (in the final analysis) to 45 young rats.
2. Room temperature, humidity and barometric pressure were not controlled.
3. Animals were used in this study and inferences from the data are open to criticism when applied to humans.

Delimitations

The following delimitations must be taken into account when making inferences from this study:

1. The effect of chronic exercise on the weight of the internal organs was the only physiological variable under investigation.
2. The exercise was continued for a period of five weeks,

for a specific amount of time each session and only one type of exercise was employed. There are a considerable number of exercise programmes in use which were not the concern of this investigation.

3. The weight of the internal organs was determined once, at the cessation of the experimental period and dehydration of the organs prior to weighing could not be controlled.

Definition of Terms

Chronic exercise as used in this study referred to any exercise programme extending over a period of several weeks, as opposed to a single bout of exercise completed in one day or less.

CHAPTER II

REVIEW OF RELATED LITERATURE

The review of related literature includes research in which humans were used as subjects as well as studies in which animals were used. The exercise programmes vary, as do the types of exercise. Only those studies concerning selected internal organs are reported. There are numerous studies on the effect of exercise on internal organs which are not the concern of this study.

The Effect of Exercise on Organ Weights

The purpose of a study by Hatai (33) in 1915 was to repeat observations made previously and to extend these observations to other organs besides the central nervous system. One month old Albino rats, litter mates, were divided into two groups. The 42 experimental animals were put in cages with a Slonaker (57) exercise wheel attached for periods of three to six months. A cyclometer recorded the number of revolutions. The 36 control animals were placed in a small (1 foot X 1 foot X 6 foot) cage in groups of five or six, so that even moderate exercise was restricted. All animals were sacrificed, dissected and the internal organs were removed and weighed. The weight of the organs was calculated corresponding to body weight. The following results were reported:

1. In all series the weight of the heart was considerably heavier (23%) in the exercised rats.
2. The kidneys showed an average difference of 19 per cent; being heavier in the exercised rats.
3. The testes averaged 12 per cent heavier in the exercised rats.

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4. The weight of the spleen was as much as 24 per cent greater in the control group.

5. In the rats exercised for the 90 to 180 day period the liver was heavier in the exercised group, while in those exercised for 30 days, the liver was heavier in the control group.

6. None of the alterations observed was as great in the rats exercised for 30 days as for those which exercised for 90 to 180 days.

7. Among normal rats kept in ordinary cages the correlation between heart weight and body length was very high, however in exercised rats this correlation was almost zero.

In the discussion of these results the investigator attributed the contrary modification in the liver of the group exercised for 30 days to a "rapid utilization of reserve materials following a rapid growth" (33:660).

Donaldson and Meeser (18) in 1932 investigated the effect of exercise (running) carried through seven generations on the organ weights of Albino rats. They reported that in both sexes the exercise caused most of the organs to become larger, except in the case of the thyroid and liver where the controls were more enlarged. The enlargement was most marked in the gonads, kidneys, suprarenals, heart and submaxillaries. Changes in organ balance following a slight amount of exercise before 56 days were marked, and were but moderately increased by exercise continued for five months or more. There was no cumulative effect of exercise from generation to generation. It was postulated that the weight changes in the organs were caused mainly by changes in the size

of the formed cells. The opinion was expressed that (18:395):

> The adjusted organ balance, which is a favorable change, is a factor in the general physiological improvement recognized as following exercise and it is highly probable that in response to moderate exercise similar changes occur in man.

These same two investigators (19) reported in 1933 on the effect of exercise beginning at different ages on the organ weights of the Albino rat. The 24 rats in Series 1 were divided into two groups at 25 days of age, the exercised group running for 31 days in a drum cage. Series 2 rats were not put in the drum cages until they were 200 days old, and the exercise was continued for 90 days. The younger rats averaged 0.6 miles per day while the older rats ran 1.2 miles per day. The control animals, all litter mates to the animals in the exercise groups, were kept in stationary cages throughout the experimental period. All of the rats were sacrificed at the termination of the particular experimental period and percentage deviations in the organ weights were determined. It was found that the value for the percentage deviations was approximately three times as great in Series 2 as in Series 1 and all of the organ weights of both exercise groups were greater than their control litter mates. As the time of running was also approximately three times as long for the Series 2 rats, it appeared that the percentage deviation was in proportion to the amount of time over which the exercise occurred. It was further reported that the glandular structures, both exocrine and endocrine, were the organs which increased in weight to the largest extent. The change in size of the organs was again attributed to changes in the size of the cells, rather than in the number of cells.

In 1935, Donaldson and Meeser (20) investigated the effect of prolonged rest following exercise on the organ weights of Albino rats. At 30 days of age 12 rats (Series 1) were placed individually in drum cages and exercised until 147 days of age. A record was kept of the activity for the last 90 days. The litter mates of this group were kept in stationary cages for an identical length of time, then all rats were sacrificed and dissected. The rats in Series 2 were treated in a similar manner to Series 1 rats, except at 147 days the rats in the exercised group were transferred to stationary cages. Six rats in each group of Series 2 were sacrificed and dissected 100 days after the cessation of exercise and six more after 150 days. These investigators reported that the plus deviations were greater in Series I than in Series 2, that is, the organ weights following a period of rest were approaching those of the controls. It was concluded that Albino rats, having run for 90 days in drum cages showed, in general, heavier organs than did their controls and that the acquired weight was due to accelerated growth. Further, after a period of rest the organs of the exercised rats were growing less rapidly than those of the controls. It was noted that 125 days of rat life is the equivalent of 10.4 years in the human life. Donaldson and Meeser stated (20:55):

> If the results are carried over to man, it follows that the modifications of the organs due to vigorous exercise, though diminishing with time, may still persist for a number of years.

Borvansky (12) used 8 Albino rats to study the effect of forced exercise for two hours daily in a drum cage. The animals were exercised for from 6 weeks to 14 months. Plus deviations were found, in the male, for the testes, kidneys, heart and suprarenals, while a minus deviation

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was found in the liver. These results were constant regardless of the length of time spent in the drum cages.

Steinhaus et al (60) using dogs as subjects, studied the effects of running and swimming on the weights of various organs. The 12 dogs were divided into three groups so that litter mates were placed in different groups. Group 1 exercised daily by running in a tread-wheel, three dogs at a time. Group 2 swam in a concrete tank daily and as they became more proficient at swimming, weights were attached to their shoulders. Group 3 was an unexercised control group. All dogs were sacrificed and the organs were removed and weighed. TABLE 1 is a summary of the results reported by these investigators. The percentage deviations indicate an increase of the exercise groups over the control group, and were calculated on an organ weight to body weight ratio.

TABLE 1

SUMMARY OF RESULTS FROM STEINHAUS ET AL (60).

	Heart	Liver	Kidneys	Spleen	Adrenals	Testes
Runners	11%	---	3%	6%	-21%	-9%
Swimmers	17%	16%	27%	-20%	28%	-38%

Those deviations expressed as a negative value indicate a reduction of the particular organ weight. It is obvious from this table that the percentage deviations, whether positive or negative, were constantly greater in the group which exercised by swimming. There was no explanation stated for this occurrence.

Asahino et al (1) recently studied the effect of excessive exercise on the sexual cycle and histological changes of various organs

in Albino rats. The rats were exercised by forced-swimming in a tank. Group A trained for either 60 days or over 90 days. Group B was castrated and four weeks after castration began 60 days of training. Group C trained for 30 days. Some of the results are as follows:

1. Adrenal Gland: In the first stage (30 days of training) there was hypertrophy of the adrenal cortex, cell infiltration, an increase in the pigmented granules, and fat deposition and hyperemia.
2. Heart: Myocardial fibres were noted to be hypertrophied in the 30-day group but there was also noted atrophy in the right ventricle fibres. In the later stage (60 days) there was an interstitial cell infiltration which reminded the investigators of myocarditis. The cartilage was also noted in the aortic valve in some cases.
3. The kidney showed an increase in the early stage followed by a gradual decrease.

Montoye _et al_ (46) investigated the effects of exercise on swimming endurance and organ weights in rats which had been raised in their small individual cages until maturity. The thirty rats were then divided into two groups, one group remaining in the small cages, the others being housed in individual cages with exercise wheels attached. Body weight was recorded at the beginning and end of the experimental period, which lasted for three months. All animals were then forced to swim until exhaustion with 6 per cent of their body weight attached. The animals were immersed in detergent solution to minimize the trapping of air in the fur and to wash the oil from the fur and then weighed under water.

All animals were sacrificed and the organs removed and weighed immediately. There was no significant difference between the following organ weights of the two groups: heart, liver, kidneys, adrenals, spleen and testes.

Hans Selye (54) investigated the effect of muscular exercise on the fat content of the liver in hooded black and white rats. The rats in Series 1 were divided into groups as follows: 1) 3 controls; 2) 3 fasted for 24 hours and then were forced to run for 4 - 1 hour periods in a 12 inch drum revolving 18 to 22 times per minute. These animals were sacrificed immediately following the last exercise bout; 3) 3 rats treated the same as those in Group 2, except these animals were allowed food between the exercise bouts. It was found that the rats in Group 1 (controls) showed no morphological signs of fatty infiltration. A chemical determination showed an average fat content of 5.2 per cent. The rats in Group 2 had a 9 per cent fat content in the liver, while those in Group 3 had 7 per cent. It was noted that, although feeding did not completely prevent fat deposition in the liver, it decreased it to some extent.

The rats in Series 2 were fasted and exercised as above. Fifteen were then given both food and water and 15 were given food but no water. The animals were sacrificed and dissected 2, 8, 24, 48 and 72 hours following the last exercise period. The rate of disappearance of fat in the liver was more rapid in the animals which were fasted through the recovery period and the amount of time necessary for the fat content to return to normal was approximately 48 to 72 hours.

The purpose of a study by Eränkö and Härkönen (24) was to determine the long-term effects of muscular work on the adrenal medulla of

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the mouse. The mice were swum, until exhaustion, 6 days a week, which was 40 minutes at the start of the experiment and approximately 4 hours by the fourth week. Lead weights were attached to the tails, the total length of the exercise period being 30 days. Seven mice were sacrificed immediately along with seven controls and seven more were sacrificed one month later with nine controls. The absolute volume of the medulla did not differ significantly from that of the corresponding control group for either experimental group. When expressed as a ratio with body weight, the group sacrificed immediately after exercise showed a significant (30 per cent) increase over the control group. There was no significant difference after the 30 day rest.

Rogers and Richter (52) reported an anatomical comparison between the adrenal glands of three types of rats: the domestic Norway (n-107), the wild Norway (n-147), and the Alexandrine (n-69). The wild rats were captured in cities. The rats were dissected and both medulla and cortex weights were determined. The adrenals of the wild group were significantly heavier than those of the domestic variety, the greatest difference being in the higher body weight ranges. There was no significant difference between the adrenals of the female wild Norway or Alexandrine, however a sex difference was noted. A reduction in the cortex size was found to be responsible for the difference in weight of the total glands, since the medulla was approximately the same size in all of the rats.

Hearn and Wainio (34) exercised rats by swimming them one-half hour daily for different lengths of time, namely 5 weeks, 6 weeks, 7 weeks or 8 weeks. These rats were pair-fed with their controls.

In every instance the heart ventricle and the adrenal glands of the exercised animals were significantly greater than their controls. It was stated that (:350)..."even though the exercise was only moderate, in that rats swim to exhaustion in about 2 hours, the physical stress was sufficient to cause physiological changes".

Effect of Exercise on the Heart

In 1928 Eyster (25) stated two theories of cardiac hypertrophy. The first, the theory of work hypertrophy, had its foundation over 300 years ago when it was noted that the diseased heart was generally larger than the normal heart. Subsequent observation showed that the increase in muscle mass occurred mainly in that part of the heart placed under a mechanical handicap as a result of a lesion and with the obvious analogy of skeletal muscle, the hypertrophy was ascribed to the increased work necessary to overcome the mechanical defect. According to Eyster, this theory has had almost universal acceptance. The theory of injury bypertrophy ascribed the increase in muscle mass to a tissue response of some nature to actual injury, rather than a physiological response to increased work. Eyster stated (25:1882):

> It would thus appear that prolonged overload or prolonged increased work is not the essential factor in the development of cardiac hypertrophy. The essential factor appears to be the stretching and injury to the heart muscle, which may be produced by a temporary overload lasting only a relatively short time.

Morehouse and Miller stated (48:105):

> Since X-ray films of athletes sometimes reveal a somewhat larger heart than is present in non-athletes, it has been thought that strenuous exertion may actually cause dilatation of the heart similar to that occurring in heart disease. The condition has been called "athletic heart"...it appears...that this is a false interpretation. The increased heart size sometimes present in

> athletes... is now believed to be due to actual hypertrophy or increase in thickness of the heart muscle entirely comparable to the hypertrophy of skeletal muscle resulting from weight lifting or similar exercises.

Steinhaus et al (61) reported roentgenographic observations on the hearts of exercise. The two groups of dogs were exercised either by running or swimming, while a third group were unexercised controls. Roentgenograms were taken bi-weekly, the area of the heart being measured through the polar planimeter method. Other measures taken from the roentgenogram were greatest length, greatest breadth at right angles to the greatest length, and the transverse length. Cardiac enlargement appeared within 3 to 5 weeks from the beginning of exercise and when exercise was discontinued for a period, the curve of the heart area flattened and the volume over weight curve showed regression of heart volume greater than body weight. It should be noted that the animals in this study were growing dogs.

Thoroughbred Greyhound racing dogs were studied by Herrmann (37) to determine the effect of strenuous exercise on the heart. The heart weights were compared to previous data Herrmann had obtained on mongrel dogs (36), where heart weight to body weight ratios of 7.98 grams were found. The largest heart was found in the oldest and most successful racer, the ratio being 17.3. Five dogs which had been trained but had raced no more than three times had an average ratio of 14.7. Two full-grown dogs which had not been schooled or raced had an average ratio of 12.3, while two pups (one-third grown) who had led a caged, sedentary life had an average ratio of 11.4. It was concluded that the Greyhound has a proportionately larger heart than mongrel dogs at birth and that this heart responds to training by hypertrophying to an unusual degree.

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McClintock _et al_ (44) studied the effect of different degrees of activity upon the weight and composition of tissue of growing Albino rats. Litter mates were divided into two groups immediately after weaning. The control group was restricted to their small individual cages which were filled with cut paper to further restrict movement. The active group was kept in revolving cages. All rats were fed _ad libitum_ and the experimental period lasted six and one-half months. The rats were sacrificed from a cut liver and during hemorrhage saline solution was injected into the femoral vein to wash the tissues free from blood. The exised heart was opened, blotted, weighed and then dried in an electric oven to a constant weight. The ratio of dried heart weight to body weight was 10 per cent higher in the active female over the inactive group but there was no significant difference in the two groups of males. It was noted that the activity of the female group (in terms of number of revolutions) was 23 per cent greater than that of the males.

Shelley _et al_ (55) exercised rats 3.3 hours daily in a water bath for 50 to 60 days. The exised hearts of the exercised rats were consistently heavier than the controls and the ratio of heart weight to body weight was also significantly increased in the swimmers. The increase in heart weight to body weight was not attributed to a loss of body weight in the exercise group.

Van Liere and Horne (64) studied the effects of exercise and other variables on the heart size of Albino rats. The rats were exercised on an electric treadmill for two hours daily at 1 mile per hour for a total of 64 hours. The animals were dissected and ratios of heart weight to body weight were calculated. The exercise group

increased in ratio of heart weight to body weight from 10 to 28 per cent over the controls.

In a later experiment Van Liere and Northup (65) used both Albino (Wistar strain) and Hooded (Long-Evans) rats in a study on Cardiac hypertrophy. The experimental group ran at 1 mile per hour on a motor driven treadmill equipped with an electric grid to keep the rats running. The length of time of the exercise session was doubled until the rats were running for two hours daily in two 1 hour periods. This was continued six days a week until a total of 64 hours was reached. The animals were sacrificed, decapitated and the heart was removed, trimmed and blotted, the ratio of heart weight to body weight calculated. Exercise caused a significant cardiac hypertrophy in both the Albino and the Hooded rats.

More recently Van Liere et al (66) investigated, among other parameters, the effect of exercise on cardiac hypertrophy in Albino rats. The exercise group ran on a treadmill as in earlier experiments, for a total of 60 hours. The heart was removed as before and weighed, then fixed in 4 per cent formaldehyde and the atria and ventricles were removed. In both sexes of rats there was a significant increase in cardiac weight to both ventricles, the increase being approximately equal in both ventricles. These investigators attributed the cardiac hypertrophy to an enlargement of the myocardial fibres produced by the increased work load.

Tepperman and Pearlman (63) examined the effects of exercise and other experimental manipulations on vessels larger than capillaries and on the heart. The 8 male rats in Group 1 ran .5 to 1.5 miles

daily in an activity cage over a period of 30 days. Group 2 consisted of 9 control animals. The 16 male rats in Group 3 exercised daily by swimming. The length of time of the exercise was 10 minutes at the start and increased 5 minutes a day until the rats swam two 30 minute bouts each day. It was noted that this was not considered to be a maximal work load. The non-swimmers (controls) were dipped in the water twice daily throught this ten week period. The fourth group was exercised the same as Group 3, but rested 8½ weeks after the cessation of exercise. Casts were made of the heart and blood vessels of all animals. In the four groups, the following results were reported:

Group 1. There was a significant degree of cardiac hypertrophy;

Group 2. There was no detectable cardiac hypertrophy;

Group 3. There was cardiac hypertrophy of borderline significance;

Group 4. There was no difference in heart weight.

A series of experiments were conducted by Stevenson _et al_ (62) to ascertain the effects of exercise of different types, frequency, and duration on the coronary tree size of rats of the Sprague-Dawley strain. All rats were fed _ad libitum_ and the exercised rats either ran on a motor driven treadmill at 15 revolutions per minute or swam in water at 23 degrees Centigrade. The experimental design of Series 1 was as follows:

1. Six rats receiving no exercise (controls).
2. Six rats ran a distance of 1.3 kilometers twice a week on a treadmill for four weeks.
3. Six rats ran a distance of 1.3 kilometers five days a week for two weeks followed by two weeks without exercise.

4. Six rats run as above with no rest period following the exercise period.

There was a significant increase in the weight of the coronary cast in Group 2 (treadmill twice weekly for four weeks) but not in any of the other groups.

The 18 rats in Series 2 were equally divided into three groups. Group 1 exercised on a treadmill (as above) twice weekly for three weeks and were fed *ad libitum*. Group 2 was treated in a similar manner except that food was deprived for 24 hours prior to every exercise session. Group 3 was deprived of food the same as Group 2 but received no exercise bouts. The ratio of heart weight to body weight in the three groups showed no significant difference.

The 24 rats in Series 3 were exercised by swimming (except Group 1, which were controls) in the following manner: Group 2 swam constantly for 60 minutes daily, 5 days a week for four weeks; Group 3 swam intermittently for 60 minutes a day, 5 days a week for four weeks and Group 4 swam constantly 60 minutes daily, twice a week for four weeks. The rats in the intermittent swimming group could place their paws on a ledge in the tank and thereby rest. It was noted that these rats spent most of the exercise period resting. The relative sizes of the coronary trees were greater in all groups over their controls, but significantly greater only in the groups which swam constantly.

Series 4 was again composed of swimming groups as follows:

1. Controls, no exercise.
2. Two 30 minute bouts of swimming (one in the morning and

on in the afternoon), 4 days weekly for 4 weeks.

3. As above, except each bout was 60 minutes in length.

4. As above, except each bout being 2 hours.

All of the coronary trees increased in the swimming groups, however the difference was significant only in the group which swam 2 hours daily. The rats which swam 4 hours daily had a significant cardiac hypertrophy relative to body weight.

Secher (53) trained rats by having them run daily in a drum for about two months. All of the rats were retired to inactivity and small groups killed at intervals up to 75 days. In the rats sacrificed immediately following exercise the heart weight constituted from 5 to 6 per cent of the body weight. This percentage decreased until the forty-eighth day, when it receeded to the normal value 3.3 to 3.6 per cent.

Boch (11) reported on various physiological parameters of a marathon runner. An X-ray film of the man's chest was interpreted as showing a slight enlargement of the heart shadow in the region of the left ventricle. An autopsy revealed a heart weight of 340 grams (average being 300 grams) and the thickness of the left ventricle wall to be 18 millimeters (average being 10 to 12 millimeters)

Gordon et al (29) studied the hearts of marathon runners through the use of roentgenography immediately following a race, 1 hour later, and with some subjects, several days after the race. The transverse diameter of the heart was divided by the transverse diameter of the chest to give a cardiothoracic ratio. In normal people this ratio should not exceed 52 per cent. None of the ratios of the marathoners

was above the normal range. "This indicated that many years of the most vigorous physical effort did not produce cardiac hypertrophy" (29:434).

The Effect of Exercise on Body Weight

Price-Jones (51) investigated the effect of exercise on several physiological and anatomical parameters in young rats. The rats were exercised in a small drum (one foot in diameter) at a rate of 8 or 9 revolutions per minute. This was continued for 5 hours on five days and 3 hours on the sixth day. The periods of observation were 36, 44 and 52 days. The rate of growth (in terms of body weight) was 1.25 to 1.44 times as great in the resting rats as compared to the active animals.

A study by Steinhaus et al (cited earlier on page 9) reported that the average body weight of dogs after exercise was less than that of their control litter mates. This difference was attributed to differences in the amount of fat in the two groups and the results were the same whether the animals were exercised by running or swimming.

Hearn and Wainio (34) reported an average daily body weight gain of 1.91 to 2.47 grams for the control group and 1.36 to 1.55 grams for the exercise group. At the cessation of the experimental period (five to eight weeks) the exercised group had gained 30 to 40 per cent less weight than did their controls. An inspection of the carcasses revealed that the controls had considerable greater omental and retroperitoneal fat deposits. The exercise group swam one-half hour daily and all exercise rats were pair-fed with a control animal.

Eränkö and Härdönen (24) also found that the experimental

group gained less weight than did the controls and following a resting period the body weight of the exercised group returned to the same level as that of the controls. The exercise group swam until exhaustion, which was 40 minutes at the beginning of the experimental period and 4 hours at the end. Some rats were sacrificed immediately following exercise (with their controls) and some one month later with their controls.

In the fifth part of a series of experiments by Stevenson et al (62) it was found that exercise groups lost weight, the amount of loss being approximately proportional to the amount of exercise. The rats swam for periods of one hour daily (in two 30 minute bouts) to 4 hours daily (in two 2 hour bouts) four times weekly for 4 weeks.

Although the mean body weight of the inactive group was 13 per cent greater than the exercise group, McClintock et al (44) reported that this difference was not significant. The rats in the experimental group were placed in revolving cages for six and one-half months while the controls were placed in small individual cages filled with cut paper to further restrict movement.

Hatai (33) reported in his study that the exercise group increased in body weight 6.67 per cent over the control group. This difference was observed in 4 of his 5 series of experiments. The exercise group was put in exercise wheels at 4 weeks of age.

The experimental animals in an investigation by Tepperman and Pearlman (63) either ran in an activity cage or swam from 10 minutes (at the start of the experiment) to one hour daily (two 30 minute bouts). After 10 weeks of exercise there was no significant difference in the

body weight of the various groups.

Donaldson and Meeser (19) investigated the effect of exercise begun at different ages on body weight and organ weights. Although most of the organs in the exercised groups increased in weight, the body weight showed no difference. This was explained as a compensatory loss of fat in the exercised animals.

TABLE II (Pages 23, 24, 25, 26) is a recapitulation of the literature cited in this study. The results of the effect of exercise on organ weights are representative of absolute organ weights except where indicated as a ratio to body weight, for example heart weight to body weight (HW/BW).

TABLE 2

SUMMARY OF RESULTS OF LITERATURE CITED

Investigator(s)	Subjects	Exercise	Effect of Exercise on Organ Weights	Effect of Exercise on Body Weight
Haitai (33)	Albino rats	Spontaneous running, 30 days or 90 to 180 days	Heart x23% Liver 30 days - 90-180 x Kidneys x19% Spleen -24% Testes x12%	x6.76%
Donaldson and Meeser (18)	Albino rats	Spontaneous running, 56 days to 5 months	Heart x Liver - Kidneys x Adrenals x Testes x	0
(19)	Albino rats	Spontaneous running, Series 1 ex. begun 25 days con. 30 days; Series 2 200 days con. 90 days	% deviations three times greater in Series 2	
(20)	Albino rats	Spontaneous running from 30 days of age to 147	Plus Deviations reported in organs	
Borvansky (12)	Albino rats	Forced running 6 weeks to 14 months 2 hours daily	Heart x Liver - Kidneys x Adrenals x Testes x	
Steinhaus et al	Dogs	Forced running and swimming	R S Heart x11% x17 Liver - x16 Kidneys x3 x27 Adrenals -21 x28 Spleen x6 -20 Testes -9 -38	- Difference due to decreased fat

(continued)

x increase of exercise group over the control
- increase in the control group or decrease in exercise group
0 no difference
(x), (-), (0) statistical treatment; significant results

[illegible]

Investigator(s)	Subjects	Exercise	Effect of Exercise on Organ Weights	Effect of Exercise on Body Weight
Asahino et al (1)	Albino rats	Forced swimming 30 days 60 days or over 90 days	Heart hypertrophy in 30 day group, atrophy in r. ventricle fibres. Kidneys x followed by - Adrenal x initially	
Montoye et al (46)	Adult Albino rats	Spontaneous running for 3 months	Heart (0) Liver (0) Kidneys (0) Adrenals (0) Spleen (0) Testes (0)	
Selye (54)	Hooded rats (Black and white)	Forced running var. series	Loss fat in liver following exercise	
Eränkö and Härkönen (24)	Mice	Forced swimming to exhaustion up to 4 hrs day for 4 weeks	Adrenal medulla (0) AW/BW ratio x	
Rogers and Richter (52)	Domestic and Wild Norway, Alexandrine	Comparison	Adrenals (x) in wild groups	
Steinhaus et al (61)	Dogs	Forced running and swimming 3 to 5 weeks	Heart x	
Herrmann (37)	Greyhounds	Racing	Heart, larger hearts than mongrels	
McClintock et al (44)	Albino rats	Spontaneous running	Heart (0)	(0)

(continued)

x increase of exercise group over the control
\- increase in the control group or decrease in exercise group
0 no difference
(x), (-), (0) statistical treatment; significant results

[illegible]

Investigator(s)	Subjects	Exercise	Effect of Exercise on Organ Weights	Effect of Exercise on Body Weight
Shelley et al (55)	Albino rats	Forced swimming 3.3 hrs day, 50 - 60 days.	Heart (x) HW/BW ratio (x)	
Van Liere and Horne (64)	Albino rats	Forced running 2 hrs daily total 64 hours	HW/BW x28%	
Van Liere and Northup (65)	Albino and Hooded rats	Forced running 2 hrs day total 64 hours	HW/BW (x)	
Van Liere et al (66)	Albino rats	Forced running 2 hrs day total 60 hours	Heart (x) to both ventricles	
Tepperman and Pearlman (63)	Albino rats	Spontaneous running and forced swimming for 10 weeks	Heart (x) in both exercise groups	(0)
Stevenson et al (62)	Albino rats	Forced running and forced swimming	Coronary cast (x) HW/BW (0) HW/BW ratio with 4 hr/day swim (x)	-
Secher (53)	Albino rats	Forced running	Hearts 5-6% of body weight, decreased to 3.3-3.6% after rest	
Boch (11)	Marathon runner		Heart x40 grams over normal average, left ventricle wall approx x7 millimeters over normal average	

(continued)

x increase of exercise group over control
- increase in the control group or decrease in exercise group
0 no difference
(x), (-), (0) statistical treatment; significant results

Investigator(s)	Subjects	Exercise	Effect of Exercise on Organ Weights	Effect of Exercise on Body Weight
Gordon et al (29)	Marathon runners		Heart none of ratios above normal average	
Price-Jones (51)	Young rats	Forced running 5 hrs/day; 36, 44 and 52 days		Growth rate x1.25 to x1.44 (times greater)
Hearn and Wainio (34)	Albino rats	Forced swimming ½ hr/day for 5 to 8 weeks		-.55 to -.92 grams/day -30 to 40% over entire period

x increase of exercise group over the control
\- increase in the control group or decrease in exercise group
0 no difference
(x), (-), (0) statistical treatment; significant results

CHAPTER III

METHODS AND PROCEDURES

Animals

The animals were male Albino (Wistar strain) rats, obtained from a local supplier of laboratory animals. At the onset of the experiment the rats were approximately five weeks of age and weighed an average of 163 grams. During the course of the experiment nine rats were destroyed for reasons unrelated to the experiment. Six rats were eliminated at the end of the experiment in order that each group have an equal number of animals. This elimination was done, without knowledge of results, such that each group was approximately equal in initial mean body weight. Therefore, of the initial 60 rats, 45 were used in the analysis of data.

Each animal was restricted to his 7 inch by 7 inch by 12 and one-half inch cage where there was little opportunity for even moderate exercise. There was no direct sunlight in the room and the temperature was maintained between 75°F and 80°F. Humidity was not controlled. The individual cages were in rows of six to a row, there being five rows of cages on either side of the rack of cages. All rats ate and drank *ad libitum* from an individual feeder and water bottle attached to the cage. Throughout the experiment the same stock diet (Rolston Labina Pellets) was used for all rats.

In the initial assignment of the rats to their individual cages it was noted that the most lively rats were removed and placed in their cages last, thereby grouping them together. All rats were assigned numbers from 1 to 60 through the use of a tag attached through the ear.

[illegible]

A table of random numbers (22:332) was therefore used to assign the rats to one of three groups: the control group, wet group, and swim group.

Testing Procedure

The rats were weighed using a triple beam balance for small animals and a correlation coefficient was calculated for the initial weight and the weight taken one day later. Following the initial weighings, the rats were weighed on the sixth day of each week for the following five weeks.

At the end of the five week period all of the animals were sacrificed in an ether chamber, weighed, and dissected. The internal organs were removed and weighed to the nearest milligram on a Fisher gram-atic balance. The organs were removed immediately following death and weighed as quickly as possible in the following order: heart, liver, kidneys, adrenals, spleen, and testes. All rats were sacrificed and dissected on the same day, and throughout the procedure one experimenter dissected, one weighed the organs, and one recorded the results.

Programme

The experimental programme was continued for five consecutive days of each week over a five week period. On the sixth day the animals were weighed and the weights recorded. The exercise programme was not continued on the seventh day.

The rats in the control group were removed from their cages every day, handled, and then returned to their cages. This was necessary to avoid viciousness in these animals due to a lack of being handled.

The rats in the wet group were removed from their cages every test

day and dipped in water until thoroughly wet. They were then dried with a towel and returned to their cages. It should be noted that these rats were held in the water by the experimenter so that they were not permitted to swim. The same water was used for this group as was used for the swim group.

The rats in the swim group swam in a cylindrical tank 27 inches in diameter and 24 inches in depth. Two rats swam at the same time. During the first week the rats swam until near exhaustion, that is, until such time as they exhibited difficulty in keeping above the surface. On the five days this time was 3 minutes, 5 minutes, 8 minutes, 15 minutes and 20 minutes. During the second week the rats swam for 10 minutes with 1 per cent (day one), 2 per cent (day two), 3 per cent (day three), 4 per cent (day four), and 5 per cent (day five) of their body weight attached to their tail. The per cent body weight was calculated on the basis of the previous sixth-day weighing. During the third week the rats swam for 15 minutes with 4 per cent of the body weight attached. The per cent body weight was again calculated on the basis of the previous sixth-day weighing. During the remaining two weeks, 5 per cent of the body weight was attached and the rats swam for 15 minutes each day. The per cent body weight was calculated as above, therefore the weights were changed according to changes in body weight following the weighing at the end of the fourth week. It should be noted that the exercise was relatively severe as two rats were drowned during the experiment.

The weights used were lead fishing weights and the pellets used in

air guns. These weights were placed in a rubber balloon, the balloon and the weights together making up the necessary per cent weight. The balloon was tied to the tail of the rat approximately one and one-half inches from the distal end.

After swimming the rats were dried with a towel and returned to their cages.

In the second week of the experiment the ears of several of the experimental animals were noted to be reddish in color and appeared to be infected. The condition was attributed to the ear tags, as only the ears with the tags were so affected. The tags were immediately removed from the ears of all the rats. The condition was not present three days after removal of the tags and the ears appeared to be normal throughout the remainder of the experiment. The tags were not replaced.

During the third week of the experiment an open area on the underside of the neck was noted on two of the experimental animals. One of these animals was destroyed and the other was immediately taken to a veterinary laboratory where it was sacrificed. A post-mortem examination revealed the lymph glands of the throat to be greatly enlarged. On culturing the open wound in that area as well as the lymph glands and many of the organs of the animal body, a staphylococcus aureus was isoloted indicating that a staphylococci septicemia had set in. A sensitivity on the staphylococci indicated treatment with a form of chloromycetin (see Document, Appendix B). The medication used was Animycetin, which was a chloramphenicol powder from Stevenson, Turner, and Boyce Limited. This medication was administered to all rats in

the drinking water in the proportion one teaspoon to one gallon of water. For the remainder of the experimental period all rats received this medication for four consecutive days every three days.

Statistical Analysis

A Pearson Product-Moment correlation coefficient was calculated to determine the reliability of the weighing procedure of body weight. In the analysis of data the organ weights were computed in their initial state (absolute weights) and also as organ weight in grams times 10,000 per gram of final body weight (relative weights). Means, variances, standard deviations, correlation coefficients, and partial correlation coefficients were obtained through the use of an I.B.M. computer. Body weight for the three groups over the five week period was investigated by the method of trend analysis, as described by Edwards (22:277) to investigate the significance of the difference between group means, trial means, and an interaction factor. One-way analysis of variance was used to evaluate the significance of difference between the organ weights (both absolute and relative) of the three groups. The .05 level of confidence was accepted for all statistical analyses performed.

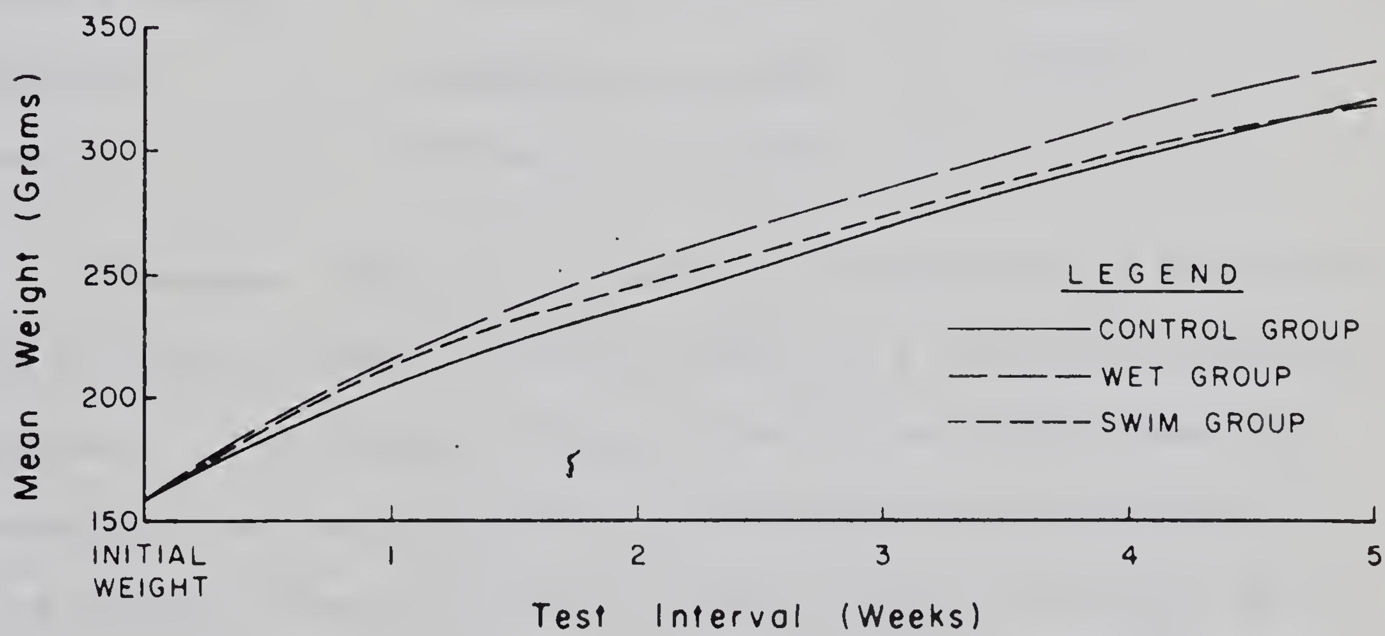
CHAPTER IV

RESULTS AND DISCUSSION

The Effect of Training on Body Weight

FIGURE I depicts the mean weight gain (calculated to the nearest gram) of the three groups over the five week period. The initial mean weights were 159.33 (control), 159.0 (wet), and 159.6 (swim). None of the initial body weight means or variances was significantly differ-

FIGURE I. MEAN WEIGHT GAIN (GRAMS)



ent from any other. It appears that the wet group gained more weight than did either of the two other groups. At the end of the fourth week the control group began to gain more weight than the swim group, and this trend continued until the end of the experimental period. However none of the differences in body weight was significant, as shown in TABLE III. The significant F ratio (noted with an asterik)

denotes the difference in trial means, that is, the mean weight gain from week to week of all subjects, or combined groups. A significant difference in weight gain from week to week would be expected in growing animals.

TABLE 3

ANALYSIS OF VARIANCE OF CHANGES IN BODY WEIGHT

Source of Variance	Sum of Squares	df.	Mean Square	F
Groups	8252.50	2	4126.25	1.22
Error (a)	142374.04	42	3389.86	
Trials	862604.87	5	172520.97	1303.03 *
Group X Trials	2506.97	10	250.70	1.89
Error (b)	27803.62	210	132.40	
Total	1043542.00	269		

Discussion. The caloric expenditure of exercise can be very high, and according to Wessel (69:305) swimming is a "very active exercise", placing it in the highest category according to energy expenditure. Although it has been stated that exercise must be continued for a long period of time to utilize one pound of fat in the body, the exercise need not be in one bout. An example given by Mayer (39:302) illustrates this fact. Splitting wood for 7 hours is the caloric equivalent of one pound of fat. It would obviously be difficult to split wood continuously for 7 hours, however, at one half-hour per day this would amount to the required time in two weeks, and if continued over a one year period would represent the caloric equivalent of 26 pounds.

Mayer also stated (39:302) that it is a misconception to assume that any increase in physical activity is always automatically followed by an increase in caloric intake. This fact was substantiated in an experiment by Whalley et al (70) on the effect of exercise on food intake in rats. These investigators reported that food intake during periods of enforced daily exercise was less than that during periods of relative rest. It was concluded that the physical stress employed (enforced exercise) depressed the desire for food in the animals.

Several investigators cited (24, 60, 62) reported that exercise caused a decreased body weight in exercised animals when compared to their non-exercised controls. Two investigators (33, 51) reported an increase in body weight following exercise and three (18, 34, 44, 63) reported that there was no difference. Two investigators (34, 60) attributed the decreased weight in exercised animals to a loss of fat in the body due to the exercise.

If it is assumed that exercise does produce a decreased fat deposit in the body, it would seem probable that it would also produce a decrease in the body weight of an exercised group of animals over those not so exercised. Several investigators (19, 34, 49, 59) have, however, found that some types of exercise cause hypertrophy in the skeletal muscles and also an increase in the weight of some of the bones. Considering these two factors together, the decreased fat content in the body would cause a decrease in the body weight which would be compensated for by an increase in the musculature. The density of the unexercised body would therefore be less than the density of the exercised body. It is largely a matter of conjecture as to the amount of exercise necessary to effect

a change in the body weight, as an increase in the density, dependent on the degree, could actually cause an increase in the body weight regardless of the loss of weight due to the reduction in total body fat.

There was no significant difference in the mean body weights of the three groups in this investigation. It would seem that, due to the fact that the exercise group had a greater caloric expenditure per day than did either of the control groups, this group may have shown a slight reduction in total body fat. The resultant loss of weight could have been compensated for by an increase in the skeletal musculature or by an increase in the caloric intake. Any differences in the mean body weights of the three groups must have been due to chance.

The Effect of Training on Organ Weights

TABLE IV indicates the mean weights of the various internal organs at the cessation of the experimental period, the mean relative weights (organ weight in grams X 10,000 per gram of body weight), and the F ratio of the analysis of variance between the three groups. On inspection of the mean absolute weights of the organs it can be seen that, with the exception of the mean spleen weight, the wet group had the heaviest organs throughout. This group was the heaviest in terms of final body weight (though not significantly) at the cessation of the experimental period. With relative weights, the heart and adrenals were heaviest in the swim group while the liver, kidneys, spleen and testes were heaviest in the control group. The F ratio was highest in both cases of the heart (absolute and relative weights). None of the differences between means was significant.

TABLE 4

MEAN ORGAN WEIGHTS OF THE THREE GROUPS

	Control	Wet	Swim	F ratio
Heart (grams)	1.035	1.121	1.085	2.33
Liver (grams)	13.314	13.457	13.037	0.19
Kidneys (grams)	2.478	2.542	2.444	0.34
Adrenals (grams)	0.0435	0.0467	0.0456	0.095
Spleen (grams)	1.154	1.133	1.111	0.12
Testes (grams)	3.153	3.159	3.111	0.12
Heart (gms/b.w)	31.198	32.344	32.889	2.65
Liver (gms/b.w)	399.545	387.040	393.314	0.57
Kidneys (gms/b.w)	74.655	73.191	74.076	0.15
Adrenals (gms/b.w)	1.318	1.347	1.386	0.56
Spleen (gms/b.w)	35.119	32.682	33.492	0.47
Testes (gms/b.w)	95.877	91.446	94.563	0.71

Discussion. Although both the absolute and relative weights of the heart were heavier in the swim group than in either of the two other groups following the period of chronic exercise in this study, the difference was not significant and therefore must be attributed to chance. With few exceptions investigators have reported cardiac hypertrophy following chronic exercise and the degree of cardiac hypertrophy appears to be proportionate to the amount of exercise. Several investigators (1, 33, 55, 61, 64) reported an increase in the heart weight after periods of exercise lasting five weeks or less. From the results of this investigation it was postulated that the exercise periods may not have been severe enough to effect a change in

the weight of the heart.

Very few studies have been made on the effect of exercise on the liver. Hatai (33) reported an increase in the weight of the liver in a group of rats exercised over a period of 30 days and a decrease in rats exercised for periods of 60 to 180 days. Donaldson and Meeser (18,19,20) and Steinhaus et al (60) both reported a decrease in the weight of the liver following exercise, and Asahino (1) reported a loss of fat in the liver following exercise. Although the absolute and relative liver weights were greater in the control group in this study, the difference was not significant and therefore can not be attributed to the experimental manipulation employed.

Several studies have been conducted on the effect of various types of exercise on the kidneys and the following changes occur in renal function during and after exercise:

1. Blood flow to the kidneys during exercise is decreased in proportion to the severity of the exercise.
2. The filtration rate is decreased in equal ratio to the renal blood flow when the blood flow changes are large but decreases very little if the blood flow changes are small.
3. Urea, creatinine, and phosphate excretion are decreased moderately and sodium chloride excretion is decreased markedly. These changes are likely due to a decreased glomerular filtration.
4. Potassium, ammonium and titratable acid excretion are decreased secondary to decreased sodium excretion.
5. Urine blood flow decreases and this decrease is attributed to decreased glomular filtration and increased antidiuretic hormone

(from the pituitary gland) production (39:270). With one exception (1) investigations have shown that chronic exercise caused an increase in the weight of the kidneys, however the magnitude (in terms of statistical significance) of this change is largely a matter of surmise. It would appear that, due to the inhibited function of the kidneys during exercise, these organs would decrease in weight following a period of chronic exercise. There was no significant difference in the kidney weights of the groups in this study and no trend could be noted from the results. Again, the severity of the exercise programme utilized in this study may not have been sufficient to cause the speculated result.

It has been noted that the weight of the adrenals increases following periods of severe stress (54) and further, some investigators have noted an increase in the weight of the adrenals following periods of exercise (12, 18, 19, 20). In the present study, even though the forced exercise appeared to cause a certain amount of stress in the animals, there was no significant difference in the weight of the adrenals following the five-week exercise period. Again this may have been due to the severity of the exercise sessions.

Very little is known on the effect of either immediate or chronic exercise on the spleen; the primary function of this organ is to store red blood corpuscles. The chronic exercise employed in this study showed no effect on the weight of the spleen.

Although a few researchers have attempted to determine the effect of chronic exercise on the testes, the results are confusing. The function of these organs during exercise may or may not be altered. There was no significant difference in the weight of the testes follow-

ing the chronic exercise in this study.

It must be noted that, for the most part, studies on the effect of chronic exercise on organ weights did not employ a statistical treatment of the data. In many of these studies differences in the weight of the organs were reported which may have been due to chance alone. It was impossible to discern the magnitude of the change when the differences were expressed as percentage deviations or as percentage increases.

Relationship Between Variables

Table 5 presents the correlation coefficients between variables.

Final body weight was highly correlated with weight gain and the absolute weights of the heart and liver. This would indicate that the heaviest rats at the cessation of the experimental period also gained the most weight during the experiment and also had the heaviest hearts and livers.

Weight gain was highly correlated with the absolute heart weight and the absolute liver weight. This would be expected in view of the correlations cited above.

There was a high correlation between absolute heart weight and absolute liver weight, that is, the rats with the heaviest livers also had the heaviest hearts. Absolute liver weight was also highly correlated with absolute kidney weight.

As the correlations were not high between the relative weights of the various organs, it would appear that either a) the various organs do not bear the same relationship to body weight, or b) the weight of the organs bears little or no relationship to body weight.

TABLE V

SIMPLE CORRELATION COEFFICIENTS * BETWEEN VARIABLES

	Final Weight	Weight Gain	Absolute Heart	Absolute Liver	Absolute Kidneys	Absolute Adrenals	Absolute Spleen	Absolute Testes	Relative Heart	Relative Liver	Relative Kidneys	Relative Adrenals	Relative Spleen	Relative Testes
Initial Weight	.516	.007	.378	.324	.247	.403	.288	.102	-.177	.068	-.185	.017	.140	-.399
Final Weight		.861	.813	.849	.670	.429	.342	.364	-.219	.267	-.106	.316	-.176	-.636
Weight Gain			.724	.798	.635	.262	.229	.364	.150	.352	-.014	-.380	-.214	-.505
Absolute Heart				.759	.649	.413	.383	.425	.388	.361	.071	-.179	-.038	-.409
Absolute Liver					.713	.422	.354	.268	-.053	.732	.110	-.201	-.074	-.550
Absolute Kidneys						.330	.218	.254	.036	.450	.664	-.184	-.137	-.419
Absolute Adrenals							.242	.253	.024	.217	.001	.715	.028	-.181
Absolute Spleen								.298	.095	.209	-.054	.011	.860	-.050
Absolute Testes									.136	.043	-.006	.002	.128	.478
Relative Heart										.220	.302	.214	.209	.328
Relative Liver											.354	.041	.094	-.168
Relative Kidneys												.065	-.009	.095
Relative Adrenals													.189	.319
Relative Spleen														.300

* A coefficient of .304 or higher is significant at .05 level.

Although all of the correlation coefficients between absolute organ weights and final body weight are significant, only two (the heart and the liver) can be considered to be high. This would explain the lack of a relationship between the relative weights of the organs. If body weight does not correlate highly with absolute organ weights, it would follow that organ weights expressed in terms of a ratio with body weight would not correlate one with the other.

TABLE VI

CORRELATION COEFFICIENTS BETWEEN FINAL BODY WEIGHT AND ORGAN WEIGHTS (ABSOLUTE AND RELATIVE) N=15

	Ab Ht	Ab Liv	Ab Kid	Ab Adr	Ab Spn	Ab Tes	Rel Ht	Rel Liv	Rel Kid	Rel Adr	Rel Spn	Rel Tes
Control	.890	.902	.555	.331	.061	.163	-.518	-.184	-.220	-.557	-.471	-.839
Wet	.762	.766	.641	.558	.333	.116	.520	.108	-.045	-.203	-.239	-.718
Swim	.840	.895	.822	.434	.629	.649	.119	.544	.069	-.143	.293	-.226

Table 6 depicts the correlation coefficients between the final body weight and the organ weights, both absolute and relative, of the three groups.

Table 7 gives the correlation coefficients of the absolute organ weights with final body weight partialled out. The only significant correlation was between the liver and kidneys.

[illegible]

[illegible]

[illegible]

[illegible]														

[illegible]

[illegible]

TABLE VII

CORRELATION COEFFICIENTS OF ABSOLUTE ORGAN WEIGHTS WITH FINAL BODY WEIGHT PARTIALLED OUT (N=45)

	Liver	Kidneys	Adrenals	Spleen	Testes
Heart	.223	.240	.123	.192	.238
Liver		.366*	.120	.128	.084
Kidneys			.063	.017	.015
Adrenals				.112	.115
Spleen					.198

Discussion. Literature regarding the relationship between body weight and the weight of the internal organs is lacking, as is data on the relationship between the weights of the various organs. In this study a very low (r=.01) correlation coefficient was found between initial weight and weight gain. The correlation coefficient was very high (r=.86) between final weight and weight gain, which would be expected. The heaviest rats at the cessation of the experimental period gained the most weight during the experiment, however this was not due to any experimental manipulation but rather to the normal growth of the animals. There was also a high correlation coefficient between the final weight of the animals and the absolute weights of the heart (r-.81) and the liver (r-.85). In the normal Albino rat, then, it appears that the heavier the rat, the heavier is the heart and liver. The correlation coefficients were not high between final body weight and the absolute weights of the other organs tested (kidneys, adrenals, spleen, and testes) so that no

[illegible]

prediction as to the weight of these organs can be made from a knowledge of the final body weight.

The absolute heart weight correlated highly (r-.76) only with the absolute liver weight, which would seem reasonable considering the correlation coefficient between the final body weight and these two organs. In normal rats it would appear that the heavier the heart is, the heavier is the liver.

The low correlation coefficients between both absolute and relative weights of the other organs can be partially explained because the weights of the organs do not seem to bear a high degree of relationship to the body weight of the rats.

It has been noted that the correlation coefficient between final body weight and the absolute weights of the heart and liver were high, though somewhat spurious, and the correlation coefficient between the absolute weights of these organs was also relatively high. The correlation coefficient between the absolute weights of the heart and liver with the body weight partialled out, however, was very low (r-.37). It would appear then, that there was little relationship between these two variables when body weight was not considered, that is, the hearts and livers of rats of equal body weight would not bear a significant relationship to one another.

CHAPTER V

SUMMARY AND CONCLUSIONS

The primary aim of this study was to investigate the effect of chronic exercise over a five-week period on the weight of selected internal organs in young rats. Secondary purposes were to investigate: the effect of chronic exercise on the body weight of young rats, the relationship between the body weight and the weight of selected internal organs of young rats, and the relationship between the weights of various internal organs of young rats.

Sixty male Albino rats (Wistar strain) approximately five weeks of age were randomly assigned to one of three groups. The control animals were restricted to their small individual cages where there was little opportunity for even moderate exercise. The wet group was treated in a similar manner to the controls, except for once each exercise day when they were dipped in the swimming tank, dried, and then returned to their cages. The swim group swam daily for five days a week for periods up to 15 minutes with up to 5 per cent of their body weight attached to their tail. During the course of the experiment nine rats were destroyed for reasons unrelated to the experiment. Six rats were eliminated at the end of the experimental period in order that each group have an equal number of animals. This elimination was done, without knowledge of the results, such that each group was approximately equal in initial mean body weight. Therefore, of the initial 60 rats, 45 were used in the analysis of data. All rats were fed *ad libitum* from a stock diet throughout the five week period.

On the sixth day of every test week the animals were weighed,

and at the cessation of the experimental period the rats were sacrificed, weighed, dissected and the organs removed in the following order: heart, liver, kidneys, adrenals, spleen and testes. The organs were weighed to the nearest milligram on a Fisher gram-atic balance as quickly as possible following their removal. The same experimenter dissected throughout the experiment and all dissections were performed on the same day.

None of the initial body weight means or variances was significantly different from any other. A trend analysis of changes in body weight of the three groups over the five-week period showed no significant difference between the three groups. The wet group had the heaviest organs (with the exception of the spleen), however it was noted that this was also the heaviest group in terms of final body weight. The difference in the weights of the organs in the three groups was not significant for absolute organ weights or for relative organ weights, that is, the weight of the organ in grams times 10,000 per gram of final body weight.

Final body weight was highly correlated with weight gain and with the absolute weights of the heart and liver, indicating that the heaviest rats at the cessation of the experimental period had gained the most weight throughout the experiment. As there was no significant difference in the body weights of the three groups this was attributed to the normal growth of the rats. The absolute heart weight correlated highly only with the absolute liver weight, which would seem reasonable considering the correlation coefficient between the final body weight and these two organs. In normal rats

it would appear that the heavier the heart is, the heavier the liver. It was found, however, that the correlation coefficient between these same two variables with the body weight partialled out was very low, indicating that this relationship would not be present in rats of equal body weight.

The following conclusions appear to be justified within the limitations of the statistical techniques employed and the population investigated:

1. Five weeks of chronic exercise had no effect on the organ weights of young rats.
2. Five weeks of chronic exercise had no effect on the body weight of young rats.
3. There is a significant and high correlation between the final body weight of young rats and the weight of the heart and the liver.
4. There was not a significant correlation between the final body weight and the weight (either absolute or relative) of the kidneys, adrenals, spleen or testes.
5. None of the six internal organs tested showed a significant relationship to one another in terms of weight.

Recommendations

1. More research should be done in the area of chronic exercise and its effects on the weight of the internal organs, and different frequencies of exercise should be employed.
2. Because some researchers have reported different results when an exercised group of animals was pair-fed with their

controls, it is recommended that this be included in an experimental design and that in addition to recording the body weight and the weight of the organs, determinations of body density be made.

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APPENDIX A

STATISTICAL TREATMENT

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STATISTICAL TREATMENT

Experimental Design

Three groups of subjects, composed of 15 rats in each group, were subjected to different experimental manipulations. The subjects were weighed at the start of the experimental period and at the end of every week for the following five weeks. At the termination of the five week experimental period the animals were sacrificed and dissected and the heart, liver, kidneys, adrenals, spleen, and testes were removed and weighed. The following determinations were made:

1. A comparison of the alterations in body weight of the three groups.

2. A comparison between the three groups of the absolute weights of the organs and the relative weights of the organs.

3. The degree of relationship between the final body weight and the weight of the various organs.

4. The degree of relationship between the weights of the various organs.

5. The degree of relationship between the absolute weights of the various organs when body weight was partialled out.

Statistical Procedures

1. Pearson's Product-Moment for the correlation coefficient between two measures of initial weight.

$$r = \frac{N\Sigma XY - \Sigma X \Sigma Y}{\sqrt{N\Sigma X^2 - (\Sigma X)^2 \quad N\Sigma Y^2 - (\Sigma Y)^2}}$$

N= number of subjects
X= initial body weight
Y= body weight one day later

2. Testing means for independent samples. (One-way analysis of variance, (27:292)).

Sum of Squares for Means:

$$\frac{T_1^2}{n_1} + \frac{T_2^2}{n_2} + \frac{T_3^2}{n_3} + \frac{T_{..}^2}{N}$$

N = total number of subjects
n_1 = number of subjects in group 1
n_2 = number of subjects in group 2
n_3 = number of subjects in group 3
T_1 = sum of raw scores in group 1
T_2 = sum of raw scores in group 2
T_3 = sum of raw scores in group 3
$T_{..}$ = sum of all raw scores

Within-groups Sum of Squares:

$$\sum\sum_{i=1}^{N} X_{ij}^2 - \left(\frac{T_1^2}{n_1} \quad \frac{T_2^2}{n_2} \quad \frac{T_3^2}{n_3}\right)$$

total sum of squared raw scores

Total Sum of Squares:

$$\sum\sum_{i=1}^{N} X_{ij}^2 - \left(\frac{T_{..}^2}{N}\right)$$

a. Significance of difference of initial body weights.

ANALYSIS OF VARIANCE OF INITIAL BODY WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	3	2	1.5	.004
Within	13214	42	314.5	
Total	13217	44		

b. Significance of difference of organ weights (absolute and relative) of the three groups.

ANALYSIS OF VARIANCE OF ABSOLUTE HEART WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	.057	2	.0285	2.3
Within	.533	42	.0122	
Total	.593	44		

ANALYSIS OF VARIANCE OF ABSOLUTE LIVER WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	1.513	2	.757	.1910
Within	166.821	42	3.972	
Total	168.334	44		

ANALYSIS OF VARIANCE OF ABSOLUTE KIDNEY WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	.076	2	.038	.34
Within	4.685	42	.112	
Total	4.761	44		

ANALYSIS OF VARIANCE OF ABSOLUTE ADRENAL WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	.00008	2	.00004	.095
Within	.00175	42	.00042	
Total	.00183	44		

ANALYSIS OF VARIANCE OF ABSOLUTE SPLEEN WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	.014	2	.007	.115
Within	2.544	42	.061	
Total	2.558	44		

ANALYSIS OF VARIANCE OF ABSOLUTE TESTES WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	.020	2	.010	.12
Within	3.233	42	.076	
Total	3.253	44		

ANALYSIS OF VARIANCE OF RELATIVE HEART WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	22.35	2	11.175	2.65
Within	177.03	42	4.215	
Total	199.38	44		

ANALYSIS OF VARIANCE OF RELATIVE LIVER WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	1172.91	2	586.4	.57
Within	43137.6	42	1027.1	
Total	44310.5	44		

ANALYSIS OF VARIANCE OF RELATIVE KIDNEY WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	16.3	2	8.15	.15
Within	2260.9	42	53.83	
Total	2271.2	44		

ANALYSIS OF VARIANCE OF RELATIVE ADRENAL WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	.035	2	.018	.56
Within	1.361	42	.032	
Total	1.396	44		

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ANALYSIS OF VARIANCE OF RELATIVE SPLEEN WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	46.2	2	23.1	.47
Within	2072.3	42	49.3	
Total	3118.5	44		

ANALYSIS OF VARIANCE OF RELATIVE TESTES WEIGHTS

Source of Variance	Sum of Squares	d.f.	Mean Square	F ratio
Means	115.4	2	77.7	.71
Within	4578.4	42	109.0	
Total	4733.8	44		

3. Testing variances for independent samples.

$$s^2 = \frac{\Sigma X - \left(\frac{\Sigma X^2}{n}\right)}{n-1}$$

S^2 = variance
X = raw scores in particular group
n = number of subjects in group

Significance of difference

$$\frac{s^2\text{(larger)}}{s^2\text{(smaller}}$$

4. Trend Analysis of changes in Body Weight. The trend analysis, as described by Edwards (22:227), was used to test the significance of differences for the changes in body weight over the five-week period.

X = individual values of body weitht, therefore ΣX = sum of 6 values for each of 45 subjects.

$A_1, A_2, \ldots, A_{45}$ = sum of 6 values of body weight for each subject.

$B_1, B_2, \ldots, B_{18}$ = sum of 15 values of body weight for each trial ie. initial weight, end of week one etc.

$C_1, C_2, \ldots, C_6$ = sum of 45 values of body weight for each trial ie. B (group 1) B, (group 2 B, (group 3) C

D_1, D_2, D_3 = sum of all values of body weight for a given group, therefore $A_1 + A_2 + \ldots + A_{15} = B_1 + B_2 + \ldots + B_6 = D_1$

Sums of Squares (ss).

a. Correction term (C.T.) $= \frac{T\Sigma x^2}{N}$

$$= \frac{68558}{270}$$

$$= 17408145.8$$

b. Total SS $= T\Sigma x^2 -$ C.T.

$$= (158^2 + 154^2 + \ldots + 286^2) - \text{C.T.}$$

$$= 1043542.21$$

c. Subject SS $= \frac{1}{n}(A_1^2 + A_2^2 + \ldots + A_{45}^2) -$ C.T.

$$= \frac{1}{6}(1477^2 + 1187^2 + \ldots + 1497^2) - \text{C.T.}$$

$$= 150626.5$$

d. Trial SS $= \frac{1}{n}(C_1^2 + C_2^2 + \ldots + C_6^2) -$ C.T.

$$= \frac{1}{45}(7136^2 + 9531^2 + \ldots + 14665^2) - \text{C.T.}$$

$$= 862604.9$$

e. Subjects X Trials = Total SS-(Subject SS+Trial SS)

$$= 30310.6$$

Degrees of Freedom

Total	= 269	
Subjects	= 44	2 groups, 42 residual
Trials	= 5	
Subject X Trials	= 220	10 groups, 210 residual

Partitioning SS (Subjects)

SS(groups) $= \frac{1}{n}(D_1^2 + D_2^2 + D_3^2) -$ C.T.

$$= \frac{1}{90}(22339 \quad 23526 \quad 22693) - \text{C.T.}$$

$$= 8252.5$$

Residual = SS(subjects)-SS(groups)

$$= 150626.5 - 8252.5$$

$$= 142374.0$$

Partitioning SS (Subjects X Trials)

TABLE

Groups	B_1	B_2	B_3	B_4	B_5	B_6
Control	2357	3073	3575	4045	4476	4813
Wet	2385	3246	3825	4286	4727	5057
Swim	2394	3212	3681	4113	4498	4795

SS(Subjects X trials) can be partitioned into:

A. groups X trials = 2 degrees of freedom (d.f.)
B. risidual = 218 degrees of freedom (d.f.)

SS(between cells in TABLE)

$$= \frac{1}{n}(B_1^2 + B_2^2 + \ldots + B_{18}^2) - C.T.$$

$$= \frac{1}{15}(2357^2 + 3073^2 + \ldots + 4795^2) - C.T.$$

$= 873364.3$

SS(groups X trials) = SS(cells)-SS(groups)-SS (trials)
= 873364.3-(8252.5+862604.9)
= 2506.97

SS(subjects X trials) = SS(groups X trials)+residual

Residual = SS(subjects X trials)-SS(groups X trials)
= 30310.6-2506.97
= 27803.6

APPENDIX B

DOCUMENT

ALBERTA

VETERINARY SERVICES BRANCH

Form V.L.-1

Veterinary Laboratory — Department of Agriculture

Edmonton, Alberta

PATH No. ______________ SECT. No. 65-2113 W

OWNER: Dept. of Physical Education, Edmonton, Alberta. DATE REC'D. June 17th, 1965.

SUBMITTED BY: DR. SECORD.

SPECIMEN: 1 LIVE RAT.

HISTORY: 60 weeks of age.
60 on the farm.
1 sick.
Fed with pellets (Purina).
Symptoms - on underside of neck there is no fur - an open wound noticed.
This was noted on both animals.
Othr Information - this rat was easy to handle - however today a bit furious.

POST MORTEM LESIONS:

In region of throat - small discharge is noted.
Mandibular lymph glands - congested and enlarged.
Gland sectioned and cultured.
Lungs - congested.
Liver congested and enlarged.
Kidney - pale.
Kidney - sectioned.
Stomach -containing a small amount of fibre content only.
Small Intestine - relatively empty.
Tissues and organs mentioned - cultured.

HISTOPATHOLOGY:

Kidney - mild degenerative changes.
Lymph gland - congestion.
Salivary gland - congestion.

COMMENT:

We found the lymph glands of throat greatly enlarged and on culturing the open wound in that area as well as the lymph glands and many of the organs of the animal body we isolated Staphylococcus aureus indicating that a Staphylococci septicemia had set in.

DIAGNOSIS: Staphylococci septicaemia

APPENDIX C

RAW DATA

CHANGES IN BODY WEIGHT OF ALL SUBJECTS

Number	Initial Weight	End of Week 1	End of Week 2	End of Week 3	End of Week 4	End of Week 5	Final Body Weight
1	158	210	241	264	291	213	387
2	154	147	159	218	242	267	377
3	140	197	182	242	282	312	323
4	146	198	244	282	319	338	348
5	153	209	245	277	296	315	324
6	270	239	290	327	356	384	389
7	143	170	186	202	231	257	260
8	176	231	274	298	324	349	358
9	162	227	268	289	313	337	342
10	161	220	267	294	329	352	361
11	146	189	230	258	290	304	303
12	163	216	260	279	309	326	336
13	156	199	243	277	312	335	345
14	186	244	278	302	323	334	353
15	143	177	208	236	259	280	286
16	180	240	278	294	321	336	348
17	136	185	206	256	285	310	319
18	140	190	227	251	271	295	297
19	152	210	242	273	300	321	331
20	155	210	253	283	312	337	345
21	143	201	254	289	307	347	363
22	187	243	278	302	325	349	360
23	185	237	275	306	328	349	358
24	150	203	238	269	305	328	336
25	147	209	250	276	306	297	303
26	147	203	241	279	317	341	351
27	171	238	281	323	359	385	407
28	143	200	242	264	306	333	304
29	181	251	290	317	353	372	380
30	168	226	270	304	332	357	374
31	158	210	241	264	291	313	321
32	144	194	223	248	272	293	300
33	123	195	228	267	288	314	326
34	146	195	192	251	274	298	301
35	147	193	222	237	257	272	281
36	157	196	230	262	288	308	308
37	157	211	237	264	285	294	302
38	154	224	271	297	332	349	354
39	146	200	252	291	340	375	394
40	185	235	267	284	303	341	356
41	190	242	272	289	308	320	334
42	192	255	298	326	356	383	398
43	154	220	244	285	312	318	332
44	158	212	252	285	309	331	340
45	183	230	252	263	283	286	299

Note: Control group 1-15, Wet group 16-30, Swim group 31-45.

RELATIVE WEIGHTS OF ORGANS OF ALL SUBJECTS

Number	Heart	Liver	Kidneys	Adrenals	Spleen	Testes
1	31.886	387.622	61.344	1.336	43.049	84.987
2	33.141	377.256	73.285	1.424	38.267	105.090
3	30.619	382.538	81.022	1.237	30.248	92.570
4	30.316	430.114	96.322	1.239	27.816	89.080
5	31.605	373.395	79.321	1.242	29.630	106.914
6	31.388	431.748	61.722	1.136	29.692	87.815
7	35.692	440.076	78.231	1.753	40.962	123.269
8	32.570	402.737	70.894	1.193	29.749	89.358
9	30.146	397.602	77.398	1.433	36.813	82.047
10	29.252	416.149	75.180	1.303	29.307	80.970
11	32.508	383.630	76.865	1.386	42.541	109.175
12	29.732	399.434	81.071	.893	30.089	94.435
13	28.783	435.449	72.261	1.234	23.304	82.609
14	29.943	365.977	72.011	1.491	37.762	98.980
15	30.385	369.440	62.902	1.474	57.552	110.839
16	33.190	379.022	73.276	1.407	31.983	84.454
17	31.724	382.476	64.953	1.487	35.110	103.103
18	31.852	422.760	71.549	1.286	36.094	101.145
19	31.903	396.978	83.142	1.464	35.921	104.444
20	31.942	372.579	78.319	1.483	34.841	85.652
21	30.799	412.121	58.678	1.164	26.309	92.948
22	31.639	316.888	66.111	1.182	23.861	84.389
23	30.475	366.117	68.631	1.320	26.816	94.218
24	33.750	401.636	77.411	1.454	35.655	81.845
25	35.974	368.613	75.380	1.227	30.924	99.709
26	35.271	376.581	80.484	1.279	38.433	102.023
27	29.189	428.599	73.096	1.223	36.314	73.120
28	32.912	377.794	72.118	1.426	37.794	92.529
29	32.421	369.210	72.000	1.271	34.105	86.895
30	32.112	434.224	82.727	1.529	26.070	85.214
31	38.567	402.959	77.944	1.526	32.399	97.726
32	31.067	364.900	68.167	1.415	27.067	89.933
33	32.761	398.957	75.859	1.452	29.785	97.485
34	34.120	383.122	83.821	1.332	32.159	113.422
35	30.427	364.982	69.004	1.301	34.021	84.484
36	32.857	385.844	69.318	1.178	27.208	93.734
37	37.119	449.370	86.225	1.500	41.192	95.828
38	32.966	382.118	77.486	1.102	32.175	93.898
39	34.162	426.167	72.589	.986	34.162	85.381
40	32.444	400.337	74.579	1.147	55.169	96.826
41	33.353	423.353	76.946	1.630	33.503	91.976
42	32.437	459.748	76.231	1.668	36.357	86.533
43	30.572	339.548	66.145	1.682	25.572	114.217
44	32.206	406.794	70.206	1.428	31.912	86.706
45	28.274	311.505	66.662	1.444	29.699	90.301

Note: Control group 1-15, Wet group 16-30, Swim group 31-45.

ABSOLUTE WEIGHTS OF ORGANS OF ALL SUBJECTS

Number	Heart	Liver	Kidneys	Adrenals	Spleen	Testes
1	1.234	15.001	2.374	.05127	1.666	3.289
2	.918	10.450	2.030	.39045	1.060	2.911
3	.989	12.356	2.617	.03995	.977	2.990
4	1.055	14.968	3.352	.04310	.968	3.100
5	1.024	12.098	2.570	.04025	.960	3.464
6	1.221	16.795	2.401	.04419	1.155	3.416
7	.928	11.442	2.034	.04558	1.065	3.205
8	1.166	14.418	2.538	.04271	1.065	3.199
9	1.031	13.598	2.647	.04900	1.259	2.806
10	1.056	15.023	2.714	.04704	1.058	2.923
11	.985	11.624	2.329	.04199	1.289	3.308
12	.999	13.421	2.724	.02999	1.011	3.173
13	.993	15.023	2.493	.04256	.804	2.850
14	1.057	12.919	2.542	.05262	1.333	3.494
15	.869	10.566	1.799	.04216	1.646	3.170
16	1.155	13.190	2.550	.04897	1.113	2.939
17	1.012	12.201	2.072	.04745	1.120	3.289
18	.946	12.556	2.125	.03820	1.072	3.004
19	1.056	13.140	2.752	.04845	1.189	3.457
20	1.102	12.854	2.702	.05115	1.202	2.955
21	1.118	14.960	2.130	.04225	.955	3.374
22	1.139	11.408	2.380	.04255	.859	3.038
23	1.091	13.107	2.457	.04727	.960	3.373
24	1.134	13.495	2.601	.04885	1.198	2.750
25	1.090	11.169	2.284	.03719	.937	3.017
26	1.238	13.218	2.825	.04489	1.349	3.581
27	1.188	17.444	2.975	.04976	1.478	2.976
28	1.119	12.845	2.452	.04848	1.285	3.146
29	1.232	14.030	2.736	.04828	1.296	3.302
30	1.201	16.240	3.094	.05720	.975	3.187
31	1.238	12.935	2.502	.04897	1.040	3.137
32	.932	10.947	2.045	.04245	.812	2.698
33	1.068	13.006	2.473	.04735	.971	3.178
34	1.027	11.532	2.523	.04010	.968	3.414
35	.855	10.256	2.939	.03655	.956	2.374
36	1.012	11.884	2.135	.03628	.838	2.887
37	1.121	13.571	2.604	.04530	1.244	2.894
38	1.167	13.527	2.743	.03900	1.139	3.324
39	1.346	16.791	2.860	.03885	1.346	3.364
40	1.155	14.252	2.655	.04084	1.964	3.447
41	1.114	14.140	2.570	.05443	1.119	3.072
42	1.291	18.298	3.034	.06637	1.447	3.444
43	1.015	11.273	2.196	.05585	.849	3.792
44	1.095	13.831	2.387	.04856	1.085	2.948
45	.844	9.314	1.992	.04318	.888	2.700

Note: Control group 1-15, Wet group 16-30, Swim group 31-45.

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